



Commercial Space Transportation

REUSABLE LAUNCH VEHICLE OPERATIONS

Safety Approval Process

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SAFETY APPROVAL PROCESS

Foreword

This document is one of several products identified in the Safety Review and Assessment Section of the Commercial Space Transportation Reusable Launch Vehicle Program Plan. The document describes a top-level process sufficiently broad to be applicable to the development and operation of all of the various reusable launch vehicle concepts. While the approval process recognizes long-term expectations including Space Launch Vehicle Approvals, similar to approvals needed in aviation, that might be associated with vehicles carrying hundreds of passengers, the focus of this document and currently proposed safety standards is on handling and managing near-term operations. Further, this plan is intended to be a living document, subject to change, as needs or circumstances dictate. The Associate Administrator for Commercial Space Transportation, the Associate Administrator for Regulation and Certification, and other Federal Aviation Administration lines of business as required, shall partner to ensure that each element of the process is thoroughly examined and executed, subject to available resources, in a manner that best serves the FAA and the commercial space transportation industry.

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1.0 INTRODUCTION

1.1 Purpose and Scope

This document is one of several products identified in the Safety Review & Assessment Section of the Commercial Space Transportation Reusable Launch Vehicle Program Plan. As noted in the Program Plan, other tasks and products are identified which would provide more specific guidance on procedures including coordination among FAA field elements and Headquarters, for example. It is anticipated that the process described herein will be subject to continuous modification and improvement as the FAA gains experience. While the approval process described recognizes long-term expectations including Space Launch Vehicle Approvals¹ that might be associated with launch vehicles carrying hundreds of passengers, the focus of this document and currently proposed safety standards is on handling and managing near-term operations. The process could be used for the licensing of vehicle operations, approvals of vehicles, systems, subsystems, components, operations and processes.

This description of the top-level process is sufficiently broad to be applicable to the development and operation of all of the various Reusable Launch Vehicle (RLV) concepts. While the focus of this process is on the approval of RLV operations, the scope may include early system and concept testing using aircraft, approaches that use aircraft as part of the launch concept, and proposals that utilize aircraft-like systems as part of the launch vehicle design. The intent is to work with the applicant in a manner, that presents an integrated corporate process leading to the ultimate goal of conducting safe RLV operations. The nature of the specific proposed concept and operation will drive the makeup of the Safety Analysis Team and the Safety Approval Plan, for example. An example of how this mirrors the process actually used for the FAA approvals of the Orbital Sciences Corporation's Pegasus/L-1011 concept is provided in the Reusable Launch Vehicle Program Plan.

1.2 Approval Authority

The safety approval criteria will be those associated with the operation being performed (e.g., aircraft modifications, aircraft operations, launch vehicle operations, testing...) and the applicable statutory authority. For launch vehicle operations, it will be the criteria identified in the Final Rules for Reusable Launch Vehicles and standards equivalent to

¹ These approvals may be analogous to those needed in aviation for passenger carrying vehicles.

those in place for launch operations to ensure safety during operation within the National Air Space. For launch and reentry operations, the required safety standards include 1) the use of a structured system safety process, 2) acceptable public risk levels, and 3) operational limitations and requirements. An Advisory Circular has been prepared to address an acceptable System Safety Process, including a System Safety Program Plan . An Advisory Circular has also been prepared presenting the methodology for determining risk to the public.

2.0 SAFETY APPROVAL PROCESS

2.1 Overview

The overall flow of the approval process is shown in figure 1. Upon receipt of a request to gain approval, or approvals, to conduct RLV operations, the process is intended to be a partnership between the FAA and the applicant similar to the FAA and Industry Guide to Product Certification. The safety approval process includes:

- assignment of an FAA team,
- assessment by the team of the requirements and resources needed for the specific proposal,
- development of an approval plan.
- notification of the requirements reflected in the approval plan.
- development by the applicant, and review by the FAA team, of design analyses, component and systems assembly and testing, and vehicle assembly and testing. In most cases, this is an iterative process beginning at conceptual design and concluding with the issuance of final approvals.

After several years of data and experience, it is anticipated that additional forms of approvals for RLVs may be appropriate. An overview of this process is reflected in Figure 1.

2.2 Applicant Requests Safety Approval

Applicant notifies FAA of intent to develop and operate an RLV: In some instances, the first step in the process may be a request for an Experimental Certificate (14 CFR 21.191) in order to conduct advanced tests key to the launch vehicle concepts or systems. In other instances, the applicant may indicate the desire to begin pre-application consultation for the purpose of submitting material in support of an application for the launch operation of a reusable launch vehicle.

- Appropriate FAA Form
- Program Letter
- Initiation of Pre-Application Consultation under 14 CFR 413.5

Figure 1. Safety Approval Process

The initial application material will contain:

- A statement of the purpose of the program describing how, where and when the program will be conducted.
- A technical description of the vehicle, system, subsystem, etc. to be approved
- A detailed description of the major milestones of the program and their purpose.
- Information on how the program will be managed, who will be involved and their qualifications
- A description of safety issues and concerns and how they plan to address them
- A description of the maintenance requirements of the system

2.3 FAA Establishes a Project (figure 1, items a and b)

Based on the submitted material, AST may seek additional information/details, or if it considers that sufficient initial information is available, establishes a safety approval project. The goal of the project is to gather the appropriate information to support a recommendation for a decision whether to approve or deny authorization to conduct a launch operation or other interim approvals as may be determined to be appropriate. This should be accomplished in the most efficient manner possible. The following action will be necessary:

- AST-1 assigns a Lead Safety Engineer to direct the project. The safety engineer will be the primary point of contact for the applicant,
- The Lead Safety Engineer will review the submittal and make an initial determination of the expertise (internal and external to AST) needed in establishing the Safety Analysis Team,
- The Lead Engineer makes a recommendation to AST-1 on the required team composition,
- AST-1 approves creation of the team. If AST needs any technical expertise from other lines of business, AST-1 requests via the Commercial Space Transportation Integrated Product Team (CST IPT) any needed technical expertise. Team resources from other lines of business are contingent upon resource availability and priorities, and must be approved by the head of the line of business (e.g., AVR-1). If certain expertise is not available within FAA, AST shall attempt to access the necessary expertise from other sources. The expertise will serve to inform the decision-making process relative to approvals of launch operations,
- Lines of business and staff organizations appoint team members who are appropriately empowered to represent their organization and accountable for their actions, and
- Notify the applicant of the project number and the name, phone number and email address of the Lead Safety Engineer

2.4 Safety Analysis Team (figure 1, items a - e)

The Safety Analysis Team (SAT) is responsible for bringing the project to a successful conclusion. Team composition is important to the success of the project. The team will:

- Have expertise in all the disciplines necessary to address the issues raised by the proposal. These include engineers, technical specialists, pilots, operations

specialists, environmental specialist, etc. It is anticipated that some team members/disciplines will come on the team and leave the team as assessment requirements, associated expertise needs, and schedules dictate,

- Identify any additional expertise that may be necessary to support the evaluation. If not available within FAA, AST shall attempt to access the necessary expertise from outside FAA. The required expertise should be continuously reassessed by the SAT.

The SAT will:

- Be organized as a matrix organization under the leadership of AST's Lead Safety Engineer. A fully integrated corporate process should be used to guide the team such that activities conducted under statutory authority other than 49 USC Subtitle IX, ch 701 (the Commercial Space Act) appropriately support the information necessary for a determination on requested launch operations,
- Identify technical, operational, and safety issues, concerns and considerations to be addressed. This is an iterative process which parallels the applicant's development process including analyses, systems selection and testing, assembly and integration, etc.,
- Attempt to define the "knowns" and unknowns and develop a plan to address them. This is an iterative process.
- Meet regularly and will provide progress reports to the Commercial Space Transportation IPT, Executive Steering Group (ESG) and/or AST-1
- Develop a statement of responsibilities, where necessary, describing expectations from each office involved in the project. As an example, the Pegasus/L-1011 project involved review and approval of modifications to the L-1011 aircraft by AVR as well as evaluation of the proposed launch operations under Part 400 by what is now AST. The statement of responsibilities not only states tasks are being performed by each organization involved, but ensures that any interface issues are addressed and that no safety issue "falls through the cracks." On the other hand, a submittal with a concept like Kistler's K-1 launch vehicle may not require any AVR involvement. The vehicle does not involve the use of an aircraft as support or aircraft-like systems and would not require aircraft type or supplemental type certification or conformity inspections by AVR. The Statement of Responsibilities is proposed by the CST IPT, subject to approval by the Executive Steering Group.

2.5 Preliminary Safety Approval Meetings

The applicant and the FAA will have one or more preliminary safety meetings to review the proposal and obtain clarification. The process will continue as long as necessary and in phase with the applicant's analyses, design, manufacturing/assembly and testing of the system and the vehicle in order to ensure a clear understanding of all aspects of the overall proposed program.

2.6 FAA Develops Safety Approval Plan

This plan, developed by the Safety Analysis Team, based on the applicant's specific proposal and input (see 2.5), will state how the FAA will conduct its approval process. The Safety Approval Plan (SAP) is the principal project coordination tool and will be updated by the Lead Safety Engineer as changes occur throughout the life of the program. The SAP will be reviewed by the CST IPT, subject to review by the Executive Steering Group prior to implementation. Where the proposed process incorporates other operations (either as part of the launch operation or as part of the applicant's testing and development program) for which the FAA has applicable statutory authority, approvals by those entities within the FAA will also be necessary for the SAP to be feasible.

The SAP will consider the applicant's proposed strategy and all available options—to the FAA and the applicant-- for addressing the issues presented by the overall project. These options should include the full range of FAA processes—where possible-- to enable and facilitate safety approvals, including, but not limited to:

- Experimental certification (14 CFR 21)
- Special conditions
- Special airworthiness certification (14 CFR 21)
- AST licensing
- Operational restrictions
- Special airspace (14 CFR 73)

The safety approval plan will also consider the decision process to be used by the team throughout the project. This process will be governed by the guidelines to be developed (see the RLV Program Plan), governing regulations and standards and how the team determines any other unique safety issues should be handled. A corporate approach based on consensus is the goal. However, the final determinations will be made by those responsible in AST for issuing launch licenses and those FAA elements elsewhere responsible for any other approvals associated with the proposed operations.

The Safety Approval Plan² will reflect the particular aspects of the proposed vehicle and operation. The Safety Approval Plan will incorporate the SAT's understanding of the specific information necessary to demonstrate that the proposed launch operations will be conducted safely and consistent with the requirements and standards identified in the Final Regulation for Reusable Launch Vehicles. For example, the Safety Approval Plan will include the specific analyses, analytical results, tests, test results, and procedures necessary to make a safety determination. The plan is expected to require updating periodically to account for changes necessary to mitigate safety issues uncovered as part of the safety review process.

² In many respects the Safety Approval Plan can be viewed achieving similar purposes as the Partnership for Safety Plan (PSP) and a Project Specific Certification Plan (PSCP) described in the FAA and Industry Guide to Product Certification, dated January 25, 1999. A similar generic document might be developed to serve as a template for each SAP specific to a particular vehicle concept.

The Safety Approval Plan will be consistent with the applicable safety standards and requirements (e.g., RLV final rules and advisory circulars) and contain the following information:

- List and composition of working groups necessary to support the project; may include structures, propulsion, life support systems, etc.,
- List of the major milestones to be completed and a schedule – this particularly will be subject to the applicant’s schedule and schedule changes,
- Description of the major issues and concerns and a proposed course of action to resolve them. (Some issues may not be evident until later in the process.) Issue papers will be used to document issues and their resolution,
- Statement of organizational responsibilities addressing the role of each office represented in the team, and
- An applicant “living” Action Item List identifying additional information/data needed from the applicant to support the safety approval process. It is anticipated that as the applicant moves through the demonstration process for launch operations including systems’ analyses, design, manufacturing/assembly and testing processes, additional safety issues will be uncovered that will need to be addressed. This is an iterative process.

2.7 Applicant is Notified of Data Requirements

After the SAP is developed the applicant is notified of any additional data needed by the FAA to process the request for safety approval. The applicant, at this point, should have a greater understanding as to the steps necessary to make an adequate demonstration based on the concept and strategy proposed as it is intended for the applicant to be involved throughout the above steps (see 2.5). The applicant is provided a reasonable time to submit the information. The data requirements may include, but not be limited to:

- Drawings and design plans,
- Performance and/or design specifications,
- System data and system analyses on performance and reliability,
- System and integrated test plans and test results—including data,
- Mission or flight rules and limitations,
- Qualification of those performing functions affecting public safety, and
- Maintenance programs (preflight, post-flight and periodic) to ensure continued flight- worthiness

2.8 Applicant Submits Additional Data

This is an iterative process requiring FAA and the applicant to be in constant communication.

2.9 Safety Analysis Team Performs Design and Operations Review (figure 1, items a – f)

Consistent with the safety standards and requirements in the final rule, the FAA SAT reviews the applicant's engineering design and analyses, proposed operational envelope, personnel qualifications, test plans, and other data. Based on the assessment, the SAT makes a determination whether the applicant should procure and assemble test articles, systems or the flight vehicle and approves testing. Absent these determinations from the FAA, the applicant proceeds at its own risk. Concurrent with this, specialized working groups will provide recommendations to the Lead Safety Engineer concerning the capabilities and limitations of the test article as these may relate to public safety. During this phase—the longest in the process, the following activities will take place:

- Safety Analysis Team and the applicant meet regularly. This may include meetings of specialized groups to consider specific aspects of the project focusing on systems and operations identified as safety critical such that the performance and reliability could affect public safety and associated risk measures. These might include structures, thermal loads and systems, propulsion, stability, guidance and control, mission rules and key personnel qualifications,
- After reviewing all data to determine the technical soundness of the applicant's proposal, the SAT provides recommendations for AST for conditional approval of applicant's plans/proposal. By "technical soundness" it is meant that: a clear and convincing demonstration has been made by the applicant that if built and/or operated in accordance with the proposed specifications and operational limitations, the item has a very high probability that it will perform as expected without posing undue public risk under the anticipated environmental conditions and satisfy the risk criteria in the final rule. Any uncertainties regarding the vehicle's performance and capabilities that could affect public safety are to be clearly mitigated,
- As the application progresses, the FAA SAT conducts conformity inspections and witnessing of activities to verify that the applicant is building, assembling, testing, and maintaining critical systems as specified in the application and documented in the approved FAA Safety Approval Plan and its updates. For example, where the concept involves an aircraft, FAA representatives responsible for ensuring compliance under of the aviation regulations would perform this. For launch vehicles, this function is also critical to public safety and AST would conduct it. As in other areas, this expertise may come from FAA engineering staff (e.g., AST), outside contractors, or a combination of FAA and contractor sources.
- The SAT performs engineering compliance determinations verifying that the article, system, vehicle, etc. was built as specified in the design drawings and specifications, including quality control of materials and assembly process. Engineering compliance also addresses integration issues among all subsystems that make up the proposed CST vehicle system,
- As this iterative process progresses, the appropriate approvals³ will be issued for the conduct of additional flight tests, and other activities that may require FAA

³ Some proposed systems involve the use of aircraft, for example, which may require certificates. The scope of this process extends only to the initial approvals for the launch license and other aircraft approvals

certification—such as experimental air worthiness certificates—launch license, vehicle registration, operational limitations, flight restrictions, etc. Where uncertainties (unknowns) exist, approvals will require the application of mitigation measures—such as operational restrictions to address safety concerns. Care shall be taken, as well, in the approval of test flights and operational restrictions to ensure “unknown unknowns”⁴ can be identified during those tests without endangering public safety. SAT members will monitor test flights for compliance with restrictions, limitations and approved procedures,

- The Safety Analysis Team conducts independent evaluations of test results—ground and flight tests, modeling, simulations, etc-- to validate applicant’s conclusions and proposed courses of action,
- Envelope expansion approvals are part of a flight test program and will be considered by the Safety Analysis Team after review of test results and other technical data. Envelope expansion should follow a well planned progression based on the results of each test with specific test objectives and appropriate public safety measures to protect the public, and
- For a launch vehicle, the ultimate objective of an envelope expansion test flight is to demonstrate the capability to reach space—requiring a launch license-- and in the case of a reusable vehicle the capability to return back to earth to a safe recovery—requiring a reentry license.

As this process is exercised with specific applicants, it is very likely that some areas of safety concern and necessary mitigation measures or requirements will be identified as candidates for inclusion in updated regulations. This “feedback” from the evaluation process to the development of standards and regulations is noted in the Reusable Launch Vehicle Program Plan.

2.10 FAA Issues a Safety Approval

The safety approval covering initial and recurring operation of the system will be issued by AST after carefully reviewing, verifying, and validating all data gathered throughout the process. The safety approval will specify:

- The name and nomenclature of the system being approved,
- The applications for which the safety approval is granted,
- Support equipment, calibration, testing and other requirements for continued flight- worthiness,
- The qualifications requirements for operators, mechanics, programmers, and other personnel needed to operate the system safely,
- Restrictions imposed on the use, deployment, and operations of the system,
- The environment and conditions (ground, atmospheric, and space envelope) in which the system must operate,

such as experimental aircraft, modifications to aircraft currently holding type certificates, etc. Approval activities that fall under the responsibility of a team member’s line of business will be the responsibility of that organization.

⁴ It is one thing to know that the answer to a particular question is unknown. It is yet another thing to not know to ask the question. The latter comprise the “unknown unknowns.”

- Approved locations for operation of the system, and
- Any other requirements needed to ensure safety

3.0 LONG-TERM VISION

3.1 After Several Years of Data/Experience

The remaining areas are considered to be long-term expectations in the regulation of reusable launch vehicles based on the view of the industry today. Undoubtedly, the approaches identified may change or be applicable in only specific areas. Some may come sooner than others. In any case, the implementation of these elements is likely to occur only after considerable flight data and experience have been gathered.

3.2 Space Launch Vehicle Class Design Validation⁵ (figure 1, items a and b)

After several licensed space launches (operational or test) to validate the vehicle's (system, subsystem, etc) design, operational performance, systems integration, reliability and, if appropriate, maintainability (of the entire system and subsystems), the applicant may choose to freeze the design and configuration (configuration control) for the purpose of manufacturing the vehicle/system. In the future, FAA/AST may consider defining space launch vehicle classes (type design) and set a minimum set of standards for each class; examples: For ELVs- 1, 2, or 3 stages/ air breathing and/or rocket systems, etc. For RLVs- air breathing and/or rocket systems / orbital / sub-orbital.

3.3 Production/Manufacture

Based on the vehicle class and the specification for that particular system and using aerospace industry manufacturing standards (including ISO-9000) the FAA Safety Analysis Team may grant safety approvals for manufacturing. Currently AST has not initiated action to develop manufacturing approval standards but as the industry evolves and the safety approval process is institutionalized, these standards will evolve. This step may involve FAA inspectors who will verify that the articles are manufactured according to the specifications and that appropriate quality controls (including batch testing and other forms of tests) are in place to assure the integrity of the manufacturing/production process.

⁵ Current indications are that it is extremely unlikely that there will be more than 1 or 2 copies of the first or second-generation of any vehicle type built. It will be more than 10 years from the start of test flights before it is possible that a vehicle designer/manufacturer will wish to produce additional copies of a vehicle for sale to other operators.